New York dairy farms and their whole-farm nitrogen and phosphorus balances and greenhouse gas footprints

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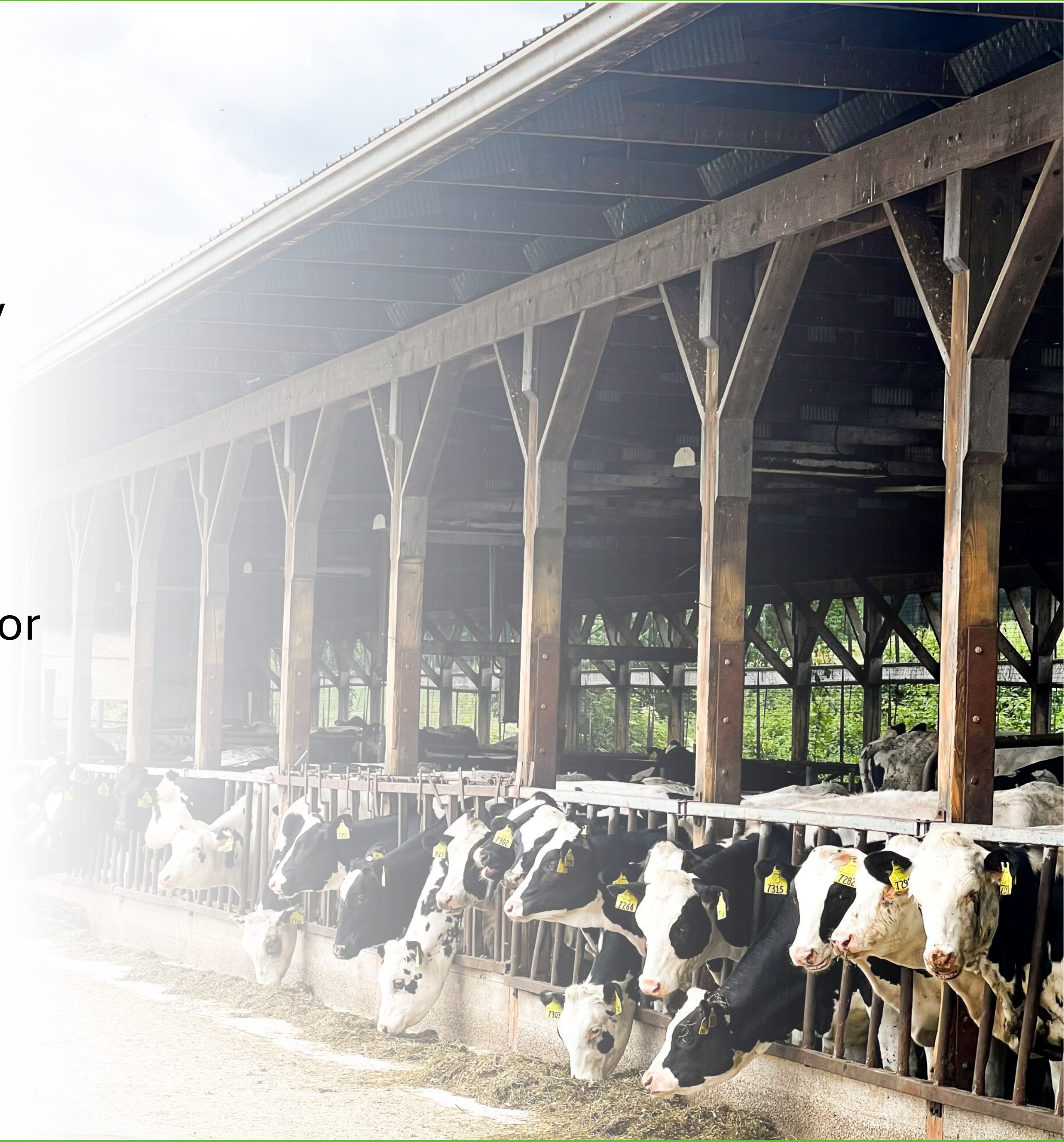
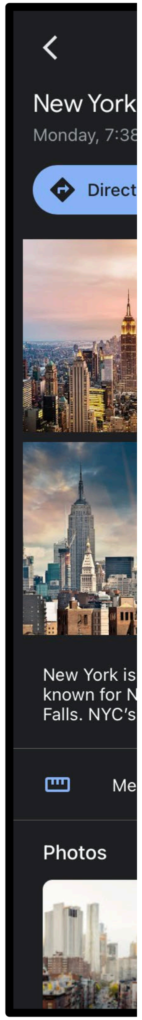
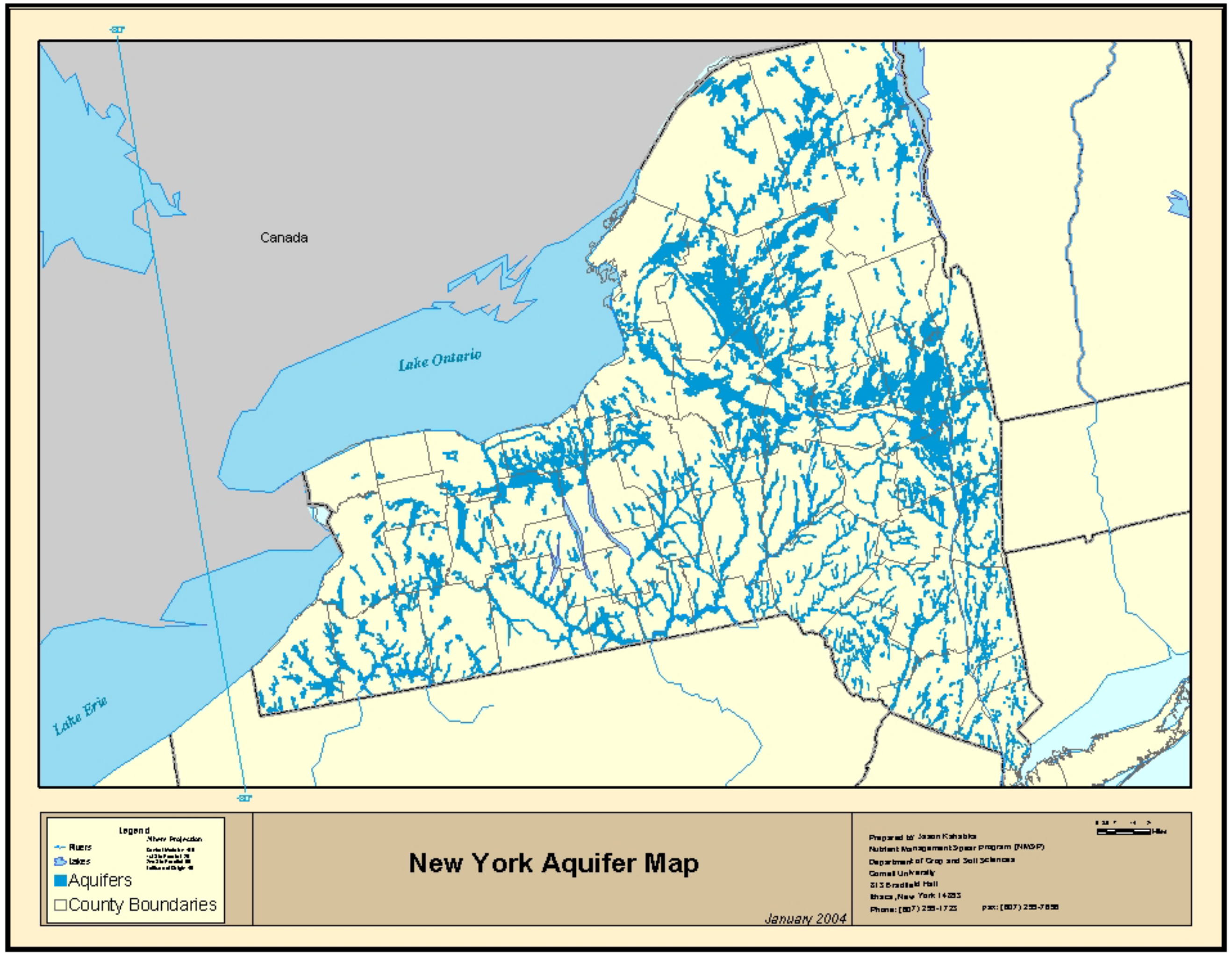
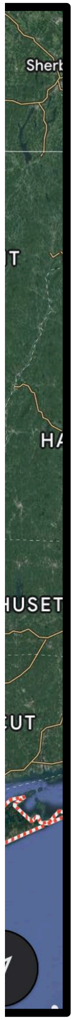


Introduction: New York agriculture







2.8 million hectares of agricultural land

Integrated crop-livestock system

Introduction: New York dairy

New York dairy industry in 2022	**Comparison to 1997**
• 5th for milk production in the US	
• 3,600 dairy farms	↓ **70%**
• 630 000 milk cows (6.7% of US total)	↓ **10%**
• 7.3 million Mg milk (7.1% of US total)	↑ **>50%**
• > $3.5 billion	

Consolidation of smaller, less productive farms to **improve efficiency**:

- More milk from fewer cows and resources
- **But** concern over the environmental impact

Source: USDA National Agricultural Statistics Service

Introduction

U.S. Dairy STEWARDSHIP COMMITMENT
Innovation Center for U.S. Dairy

INDUSTRY-WIDE GOALS BY 2050		
GHG		
Achieve greenhouse gas neutrality	Optimize water use while maximizing recycling	Improve water quality by optimizing utilization of manure and nutrients

Expected 20% ↑ milk demand in New York

No New York or US studies on greenhouse gas emissions of large, commercial dairy farms using **actual farm data**

?

How do farms currently perform?

What progress have they already made?

How achievable are these goals?

How can farms make progress towards them?

Source: US Dairy

U.S. Dairy
STEWARDSHIP
COMMITMENT
Innovation Center for U.S. Dairy

Objectives

1. Calculate whole-farm nitrogen (N) and phosphorus (P) balances

2. Estimate total farm-gate greenhouse gas emission intensity (GHG_{ei})

3. Identify any common key performance indicators (KPIs)

First New York and US study to calculate whole-farm footprints for N, P and GHGs using actual farm data.

Materials and methods

Total milk production = 870 000 Mg

12% of total NY milk production in 2022

- 36 large (> 300 mature cows) **commercial** dairy farms
- Located in **all regions** of New York selling to four different co-ops
- Predominantly **Holstein** cows in all herds
- Average herd size = **2 100 milk cows** (range = 345 – 6 350)
- Average animal density = **3.16 AU ha^{-1}** (range = 1.76 – 4.85)
- Average annual milk yield = **12 700 kg FPCM cow^{-1}** (range = 11 400 – 13 900)
- Average homegrown feed = **64%** of total feed DM (range = 49-84%)
- Average crude protein content of feed = **15.6%** (range = 12.8 – 17.2)
- Average phosphorus content of feed = **0.36%** (range = 0.29 – 0.71)
- Average herd feed consumption intensity = **0.67 kg DM kg FPCM^{-1}** (range = 0.55 – 0.80)

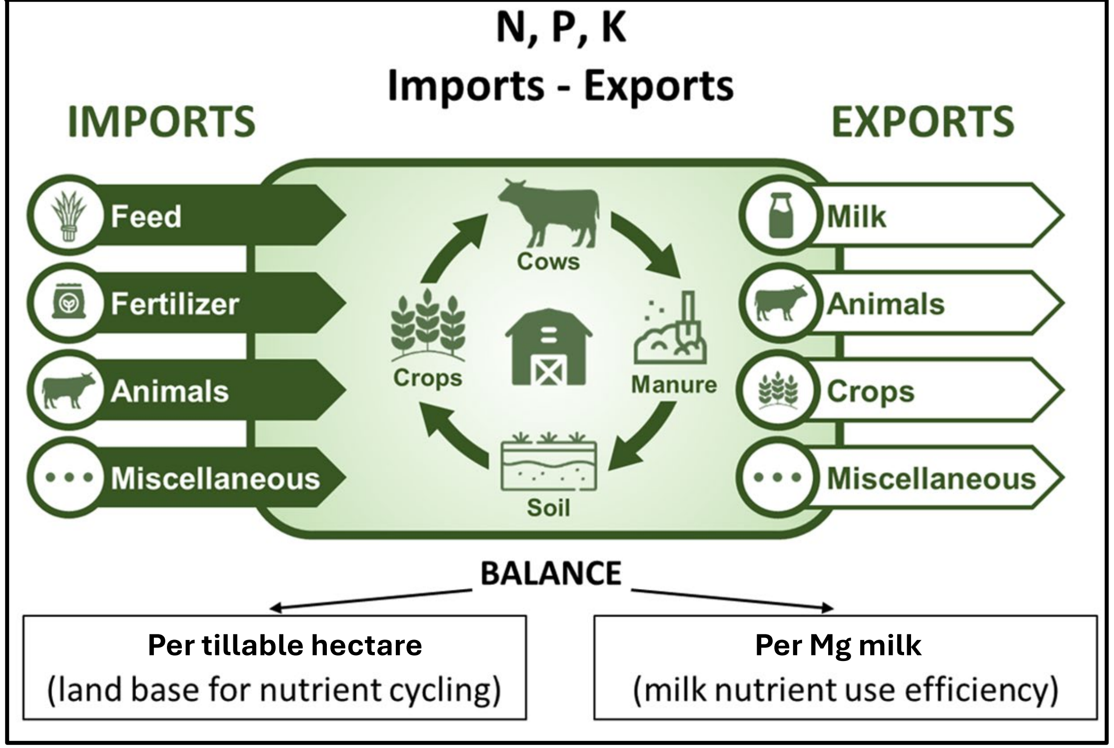
Materials and methods

- Predominant manure systems:
  - Open liquid storage = **25 farms, 51%** of milk
  - Anaerobic digesters = **8 farms, 41%** of milk
  - Solid liquid separation (SLS) with cover and flare = **3 farms, 8%** of milk produced
- Crop rotation
  - Typically **4 – 5 year corn and alfalfa/grass** rotation
  - Double cropping of rye or triticale: **7 farms**
  - Cover cropping: **47%** of corn acres (range = 0 – 100%)
  - Acres in continuous reduced till = **21 farms, 52%** of total acres

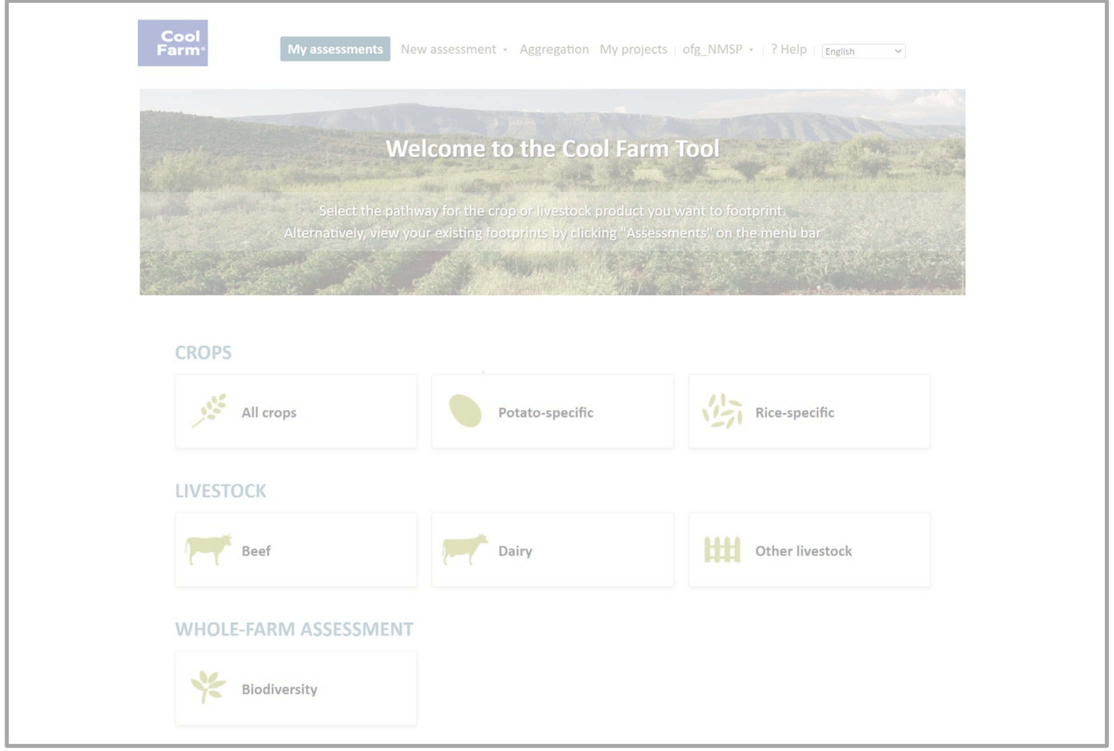
Materials and methods

- Two tools
  - Whole-farm assessment
  - Comprehensive results from relatively easy to obtain data

Cornell nutrient mass balance calculator

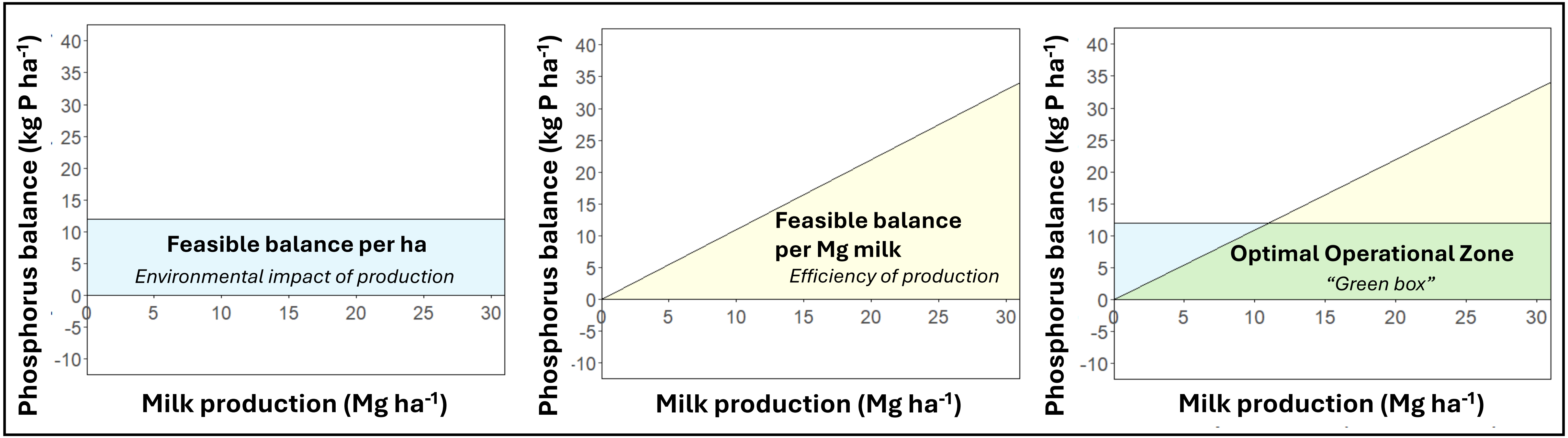


Cool Farm Tool® greenhouse gas emissions



Materials and methods

- Feasible balances
  - Farms can compare themselves to peers
  - Have something to strive for



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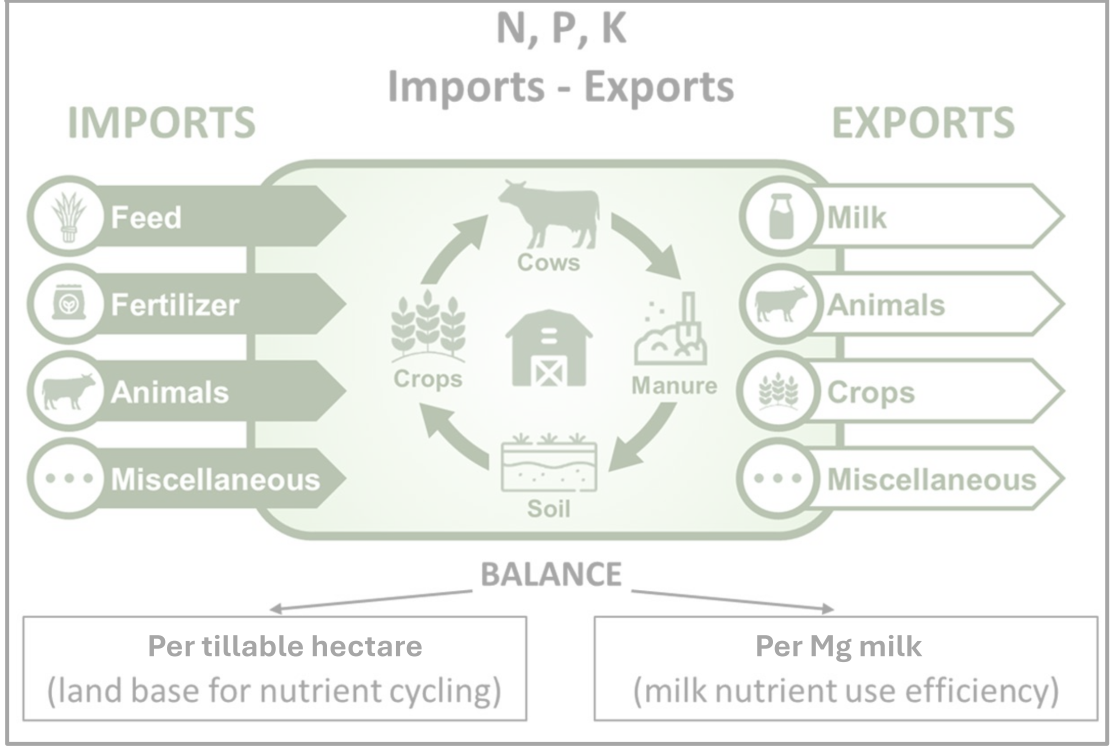
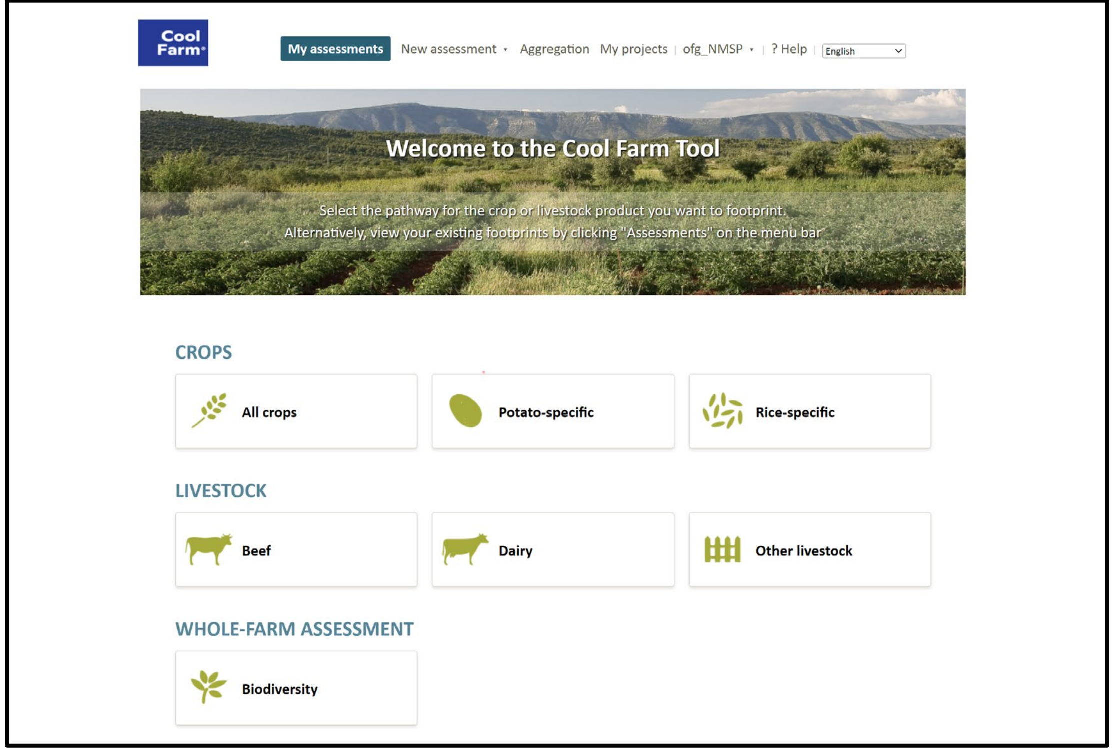
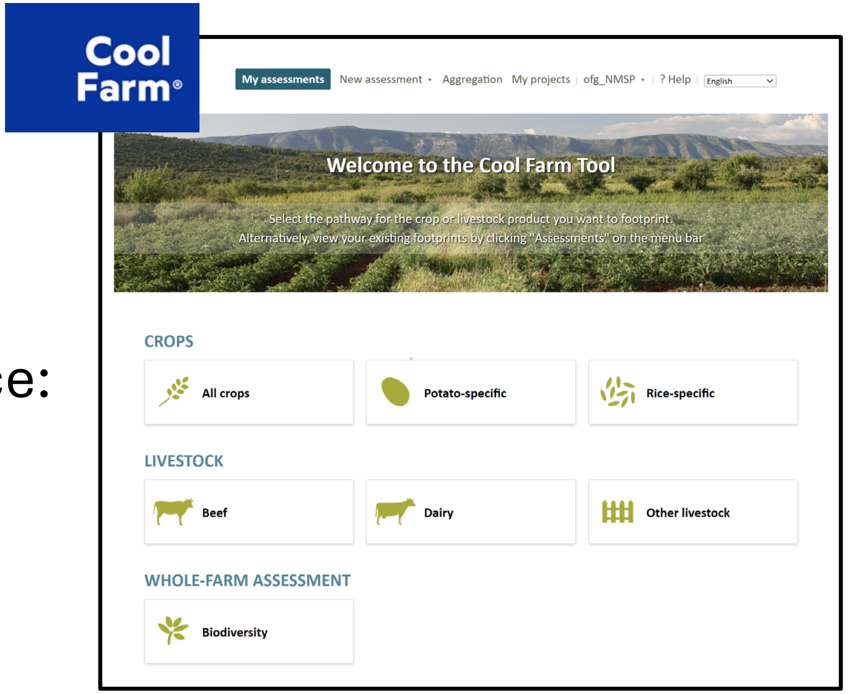


Cool Farm Tool® greenhouse gas emissions



Materials and methods



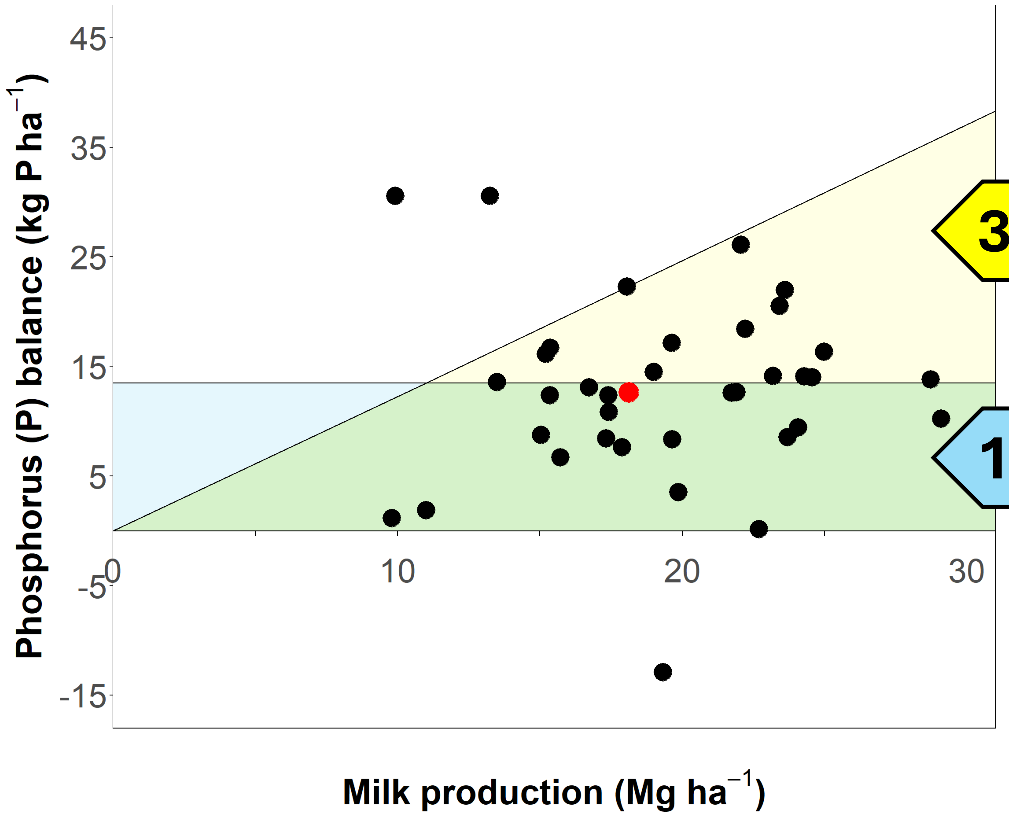
- IPCC 2019 methodology, AR6 100-year GWPs
- Crop, animal and whole-farm emissions by GHG and source:
  - Feed production: fertilizer, soils, tillage, cover crops
  - Grazing management
  - Enteric emissions
  - Manure management
  - Fuel, energy use and transport
- Ability to track progress made
- Can identify potential for further improvement

Allows assessment of integrated crop-livestock systems

Continuous development

Results: Nutrient mass balances

Phosphorus balance



33 farms meet the feasible balance per Mg milk

19 farms meet the feasible balance per hectare

Average P balances:

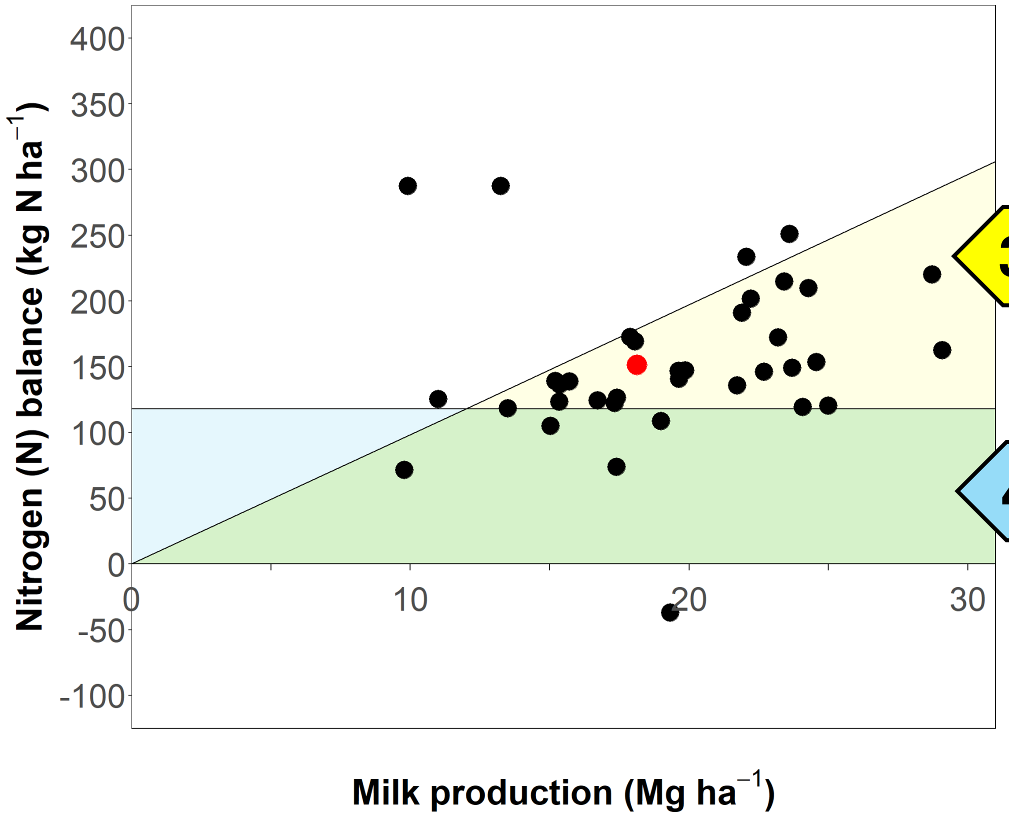
13 kg P ha^{-1}

0.6 kg P Mg milk^{-1}

19 farms in the Green Box

Results: Nutrient mass balances

Nitrogen balance



30 farms meet the feasible balance per Mg milk

4 farms meet the feasible balance per hectare

Average N balance:

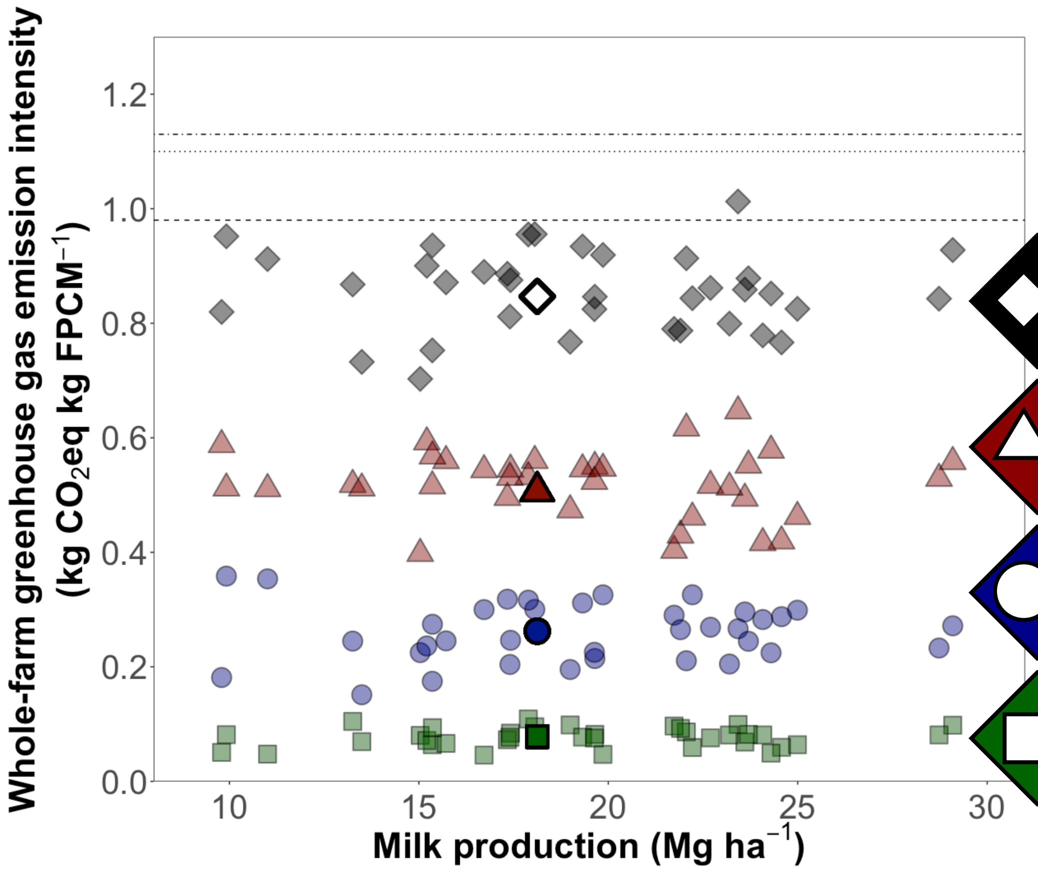
153 kg N ha^{-1}

7.7 kg N Mg milk^{-1}

4 farms in the Green Box

Results: GHG_{ei} breakdown by gas

Greenhouse gas emissions by gas



Potential carbon removal estimate (sequestration):
Average = **-0.02** kg CO_2eq, range = -0.07- 0.00

1.13 kg CO_2eq kg $FPCM^{-1}$ – North American average – FAO, 2022
1.10 kg CO_2eq kg $FPCM^{-1}$ – NY organic – Olivo et al., 2024
0.98 kg CO_2eq kg $FPCM^{-1}$ – Northeast USA – Rotz et al., 2021

Total emissions:
Average = **0.86** kg CO_2eq kg $FPCM^{-1}$, range = 0.70 – 1.01

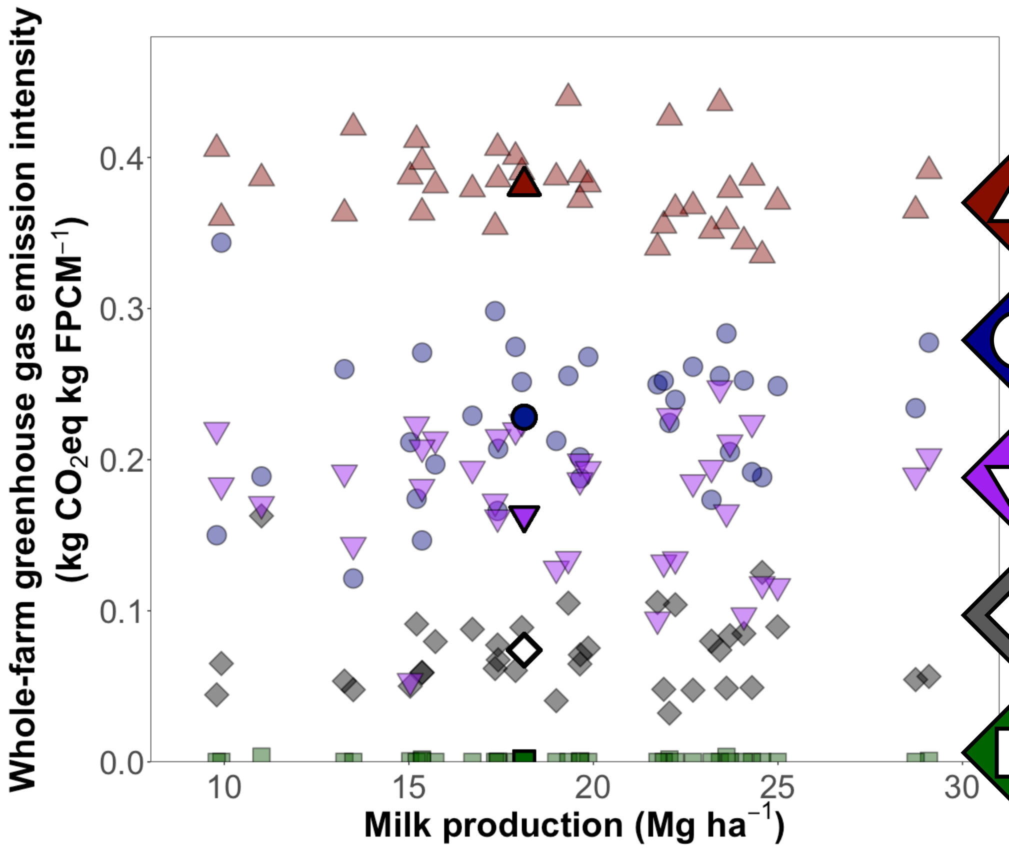
Methane (CH_4) emissions = **61%** of total emissions
Average = **0.52** kg CO_2eq kg $FPCM^{-1}$, range = 0.40 – 0.65

Carbon dioxide (CO_2) emissions = **30%** of total emissions
Average = **0.26** kg CO_2eq kg $FPCM^{-1}$, range = 0.15 – 0.36

Nitrous oxide (N_2O) emissions = **9%** of total emissions
Average = **0.08** kg CO_2eq kg $FPCM^{-1}$, range = 0.05 – 0.11

Results: GHG_{ei} breakdown by source

Greenhouse gas emissions by source



Potential carbon removal estimate (sequestration):
Average = **-0.02** kg CO_2eq, range = -0.07- 0.00

Enteric emissions = **45%** of total emissions
Average = **0.38** kg CO_2eq kg $FPCM^{-1}$, range = 0.34 – 0.44

Feed production emissions = **26%** of total emissions
Average = **0.23** kg CO_2eq kg $FPCM^{-1}$, range = 0.08 – 0.42

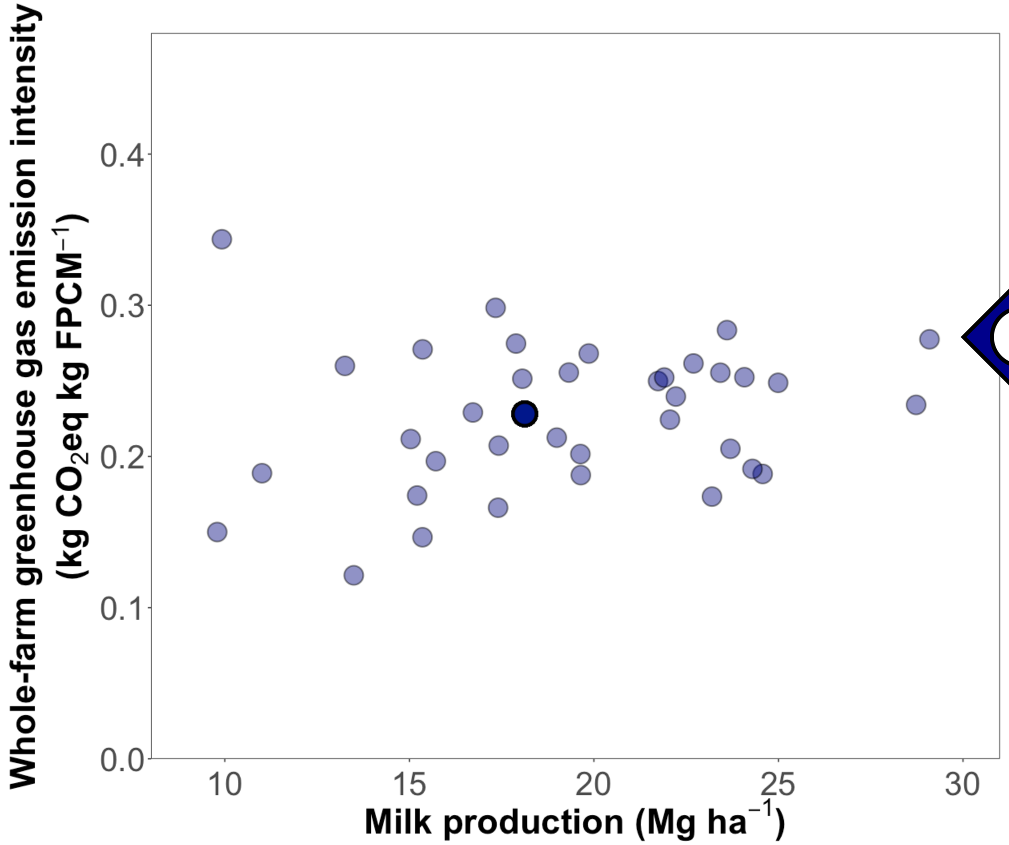
Manure management emissions = **20%** of total emissions
Average = **0.18** kg CO_2eq kg $FPCM^{-1}$, range = 0.05 – 0.25

Energy, fuel and transport emissions = **8%** of total emissions
Average = **0.07** kg CO_2eq kg $FPCM^{-1}$, range = 0.03 – 0.16

Grazing emissions = **<0.01%** of total emissions
Average = **<0.01** kg CO_2eq kg $FPCM^{-1}$, range = 0.00 – <0.01

Results: GHG_{ei} of feed production

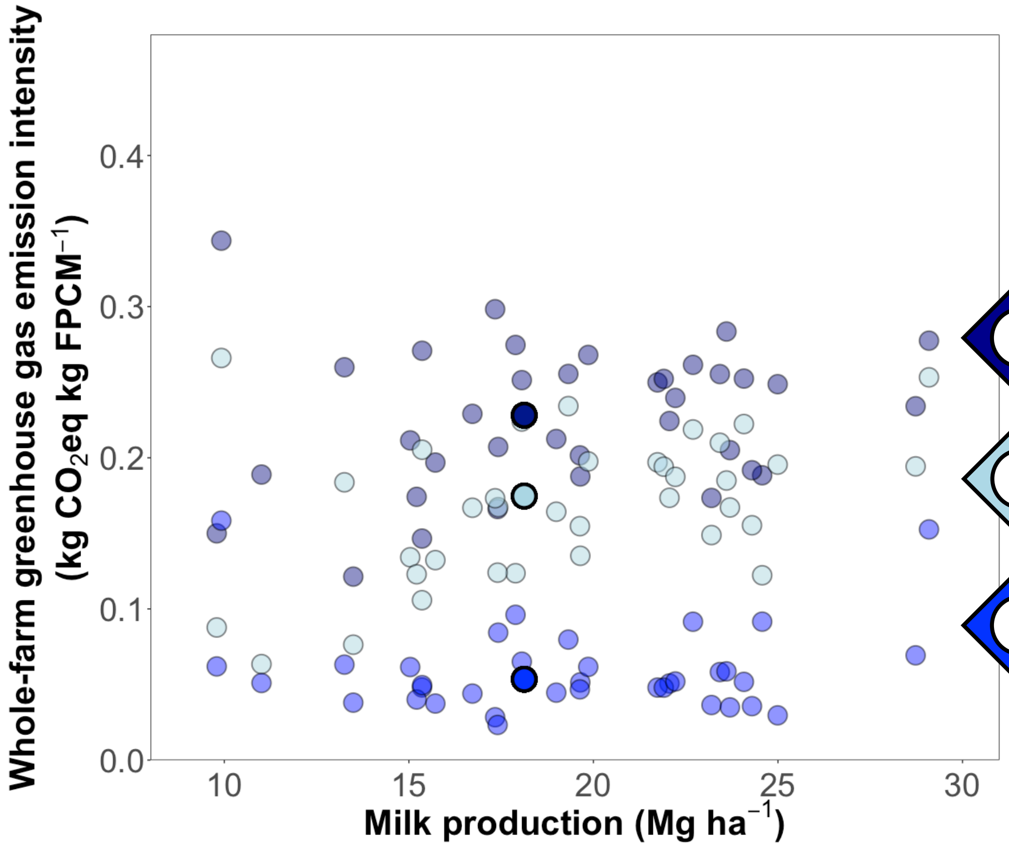
Greenhouse gas emissions by source



Feed production emissions = **26%** of total emissions
Average = **0.23** kg CO_2eq kg $FPCM^{-1}$, range = 0.08 – 0.42

Results: Greenhouse gases

Greenhouse gas emissions by source



64% of feed is homegrown, but accounts for **only 27%** of the feed production emissions

- High yields
- Low synthetic fertilizer use

Feed production emissions = **26%** of total emissions
Average = **0.23** kg CO_2eq kg $FPCM^{-1}$, range = 0.08 – 0.42

Purchased feed production emissions = **73%** of feed emissions
Average = **0.17** kg CO_2eq kg $FPCM^{-1}$, range = 0.06 – 0.27

Homegrown feed production emissions = **27%** of feed emissions
Average = **0.06** kg CO_2eq kg $FPCM^{-1}$, range = 0.02 – 0.15

Results: Summary

	Phosphorus		Nitrogen		Carbon	
	kg P ha^{-1}	kg P Mg $FPCM^{-1}$	kg N ha^{-1}	kg N Mg $FPCM^{-1}$	Mg CO_2eq ha^{-1}	kg CO_2eq Mg $FPCM^{-1}$
Feasible range	>0 and ≤13	>0 and ≤1.1	>0 and ≤118	>0 and ≤8.8		
Weighted mean (range)	**13** (-13 - 31)	**0.6** (-0.7 – 1.3)	**153** (-37 - 287)	**7.7** (-1.9 – 12.3)	**15.3** (8.0 – 27.0)	**0.86** (0.70 – 1.01)
No. farms in feasible range	19 / 36	33 / 36	4 / 36	30 / 36	-	-
No. farms in Green Box	19 / 36		4 / 36		-	
Key drivers	Feed P imports R^2=0.45, *P*<0.001 Manure exports R^2=0.46, *P*=0.001 **Animal density R^2=0.22, *P*=0.004**		Feed N imports R^2=0.60, *P*<0.001 **Animal density R^2=0.36, *P*<0.001** %CP of feed R^2=0.24, *P*=0.003 Manure exports R^2=0.22, *P*=0.043		Manure system R^2=0.35, *P*<0.001 Feed consumption intensity R^2=0.17, *P*=0.012 **Animal density R^2=0.13, *P*=0.028** Heifer to cow ratio R^2=0.11, *P*=0.047	

! Farms with **high nitrogen balances** tend to have higher phosphorus balances and GHG emissions

Conclusions

- Large (>300 mature cows) dairy farms representing 12% of NY milk production in 2022
- Good management of **phosphorus**
- Efficient use of **nitrogen**, but opportunities to reduce balances per hectare
- GHG emission intensity is **below** published averages for the region
  - No small farms included
  - Different model used for evaluation
  - Actual farm data vs. representative farm inputs
- **Win-win opportunities** that are actionable today:
  - Reduce animal density and heifer to cow ratio
  - Capitalize on high quality homegrown feeds to reduce feed imports

Future work

- Mitigation opportunities – what has already been achieved?
- What is the optimum animal density?
  - Heifer to cow ratios
  - Replacement rates
- How can we maximize homegrown feed production?
  - Capitalize on NY's integrated crop livestock system
  - Look at rotations and double cropping opportunities
  - Building relationships with cash crop neighbors for manure exports
- Consider impacts on total emissions, not just emission intensity
  - Particularly if milk demand/cow numbers increases 20% as predicted
- How do these farms compare to smaller farms in NY?
- How do these farms compare to large farms in other regions?

Continue to work **directly** with farmers to understand their needs and grow voluntary participation

How can we help the farmers to achieve **their** goals, alongside industry goals?

Thank you!

This work is not possible without the invaluable data and feedback provided by New York dairy farms and the support of their nutrient management planners, nutritionists and advisors.

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